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THE TERM STRUCTURE OF LIBOR STERLING RATES*

Summary: A three-variable VAR including the yield spread, the change in the short rate and the excess holding period yield is used to test for the validity of rational expectations hypothesis of the LIBOR sterling rates term structure. In doing so the monthly series of one, three, six and twelve month LIBORs from the period January 1978-June 2009 are utilized, all supplied by the Bank of England. The main findings from the analysis include these that for all maturities considered the yield spread Granger causes future changes in the one month rate, the term premia are not time-varying, and variation in the unexpected returns is due to news about the future one month rates and not due to news about the future term premia.

Key words: term structure of interest rates, rational expectations hypothesis, time varying term premium, London Interbank Market, VAR, JEL classification: C32, E43.

1. Introduction

The rational expectations hypothesis of the term structure (REHTS) posits that the yield spread between the long interest rate and the short interest rate is the optimal predictor of future changes in the short rates over the life of the ”long bond” [Campbell, Shiller 1991]. The empirical analysis in the U.S. and other mature markets has revealed that the yield spread predicts future changes in short rates in the right direction, nevertheless actual movements in the spread are greater than those required by the REHTS [Shiller et al. 1983; Shiller 1990; Campbell, Shiller 1991; Hardouvelis 1994; Evans, Lewis 1994; Engsted, Tanggaard 1995; Rudebush 1995; Backus et al. 2001; Christiansen 2003]. This is often referred as to “the overreaction hypothesis” [Mankiw 1986; Froot 1989; Campbell, Shiller 1991; Hardouvelis 1988, 1994; Cuthbertson, Bredin 2001; Cuthbertson, Nitzsche 2003][1]. The natural explanation of

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[1] The REHTS better performs during a monetary targeting than an interest rates smoothing conducted by monetary authorities. This is why interest rates stabilization may result in that the short rate behaves as a random walk. Then the expected change in short rates is zero and the spread has no

this phenomenon is that of the omission in the regression a time-varying term premium which is included in long rates to compensate investors in the bond market for holding less liquid assets then the short term bonds. Its volatility and correlation with the yield spread causes a downward bias of the slope coefficient of the term spread model of the term structure [Fama 1984; Mankiw 1986; Hardouvelis 1998, 1994; Tzavalis, Wickens 1997; Harris 2001]. It has also been showed that in case the short rate is persistent or its generating mechanism is nonlinear the conventional regression tests and the Campbell-Shiller VAR tests of REHTS are severely biased even in large samples [Bekaert, Hodrick, Marshall 1997; Garganas, Hall 2004].

In order to overcome this problem the use of a three-variable VAR including the yield spread, the change in the short-term interest rate, and the excess holding period return has been proposed but exceptionally employed for testing purposes in the bond [Tzavalis, Wickens 1998, Tzavalis 2003 (U.S.A.); Cuthbertson, Bredin 2001 (Ireland)] and the interbank [Cuthbertson, Nitzsche 2003 (UK), Blangiewicz, Miłobędzki 2009 (Poland)] markets[2]. In all cases a strong predictive power of the yield spread has been confirmed and apart from the Irish market the existence of a time-varying term premium has been revealed.

The purpose of this paper is to test for the validity of REHTS in the London Interbank Market. The LIBOR rates (*London Interbank Offered Rates*) quoted there are the primary benchmark rates that are used by investors, banks and securities houses to gauge the cost of unsecured borrowing in the money markets. Hundreds trillion of swaps and loans are indexed to the LIBORs worldwide. They are also the basis for settlement of interest rate contracts on many major future and option exchanges (CME Group, NYSE Euronext LIFFE)[3]. The analysis is nested within a three-variable VAR framework. The estimation and testing are performed on the set of monthly sampled sterling LIBORs for maturities of one (1M), three (3M), six (6M) and twelve (12M) months from the period January 1978-June 2009, supplied by the Bank of England[4]. The computations are performed using GAUSS 9.0.

The remainder of the paper proceeds as follows. Section 2 introduces the REHTS and describes its testing within the VAR framework. Section 3 discusses the empirical results. The last section briefly concludes.

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predictive power for the short rate [Mankiw, Miron 1986; Hardouvelis 1988; Rudebush 1995; Roberds et al. 1996].

[2] This is an extension of the two-variable VAR of Campbell and Shiller 1987, 1991, in which the excess holding period return exhibits a time-varying term premium. King and Kurman 2002 showed the equivalence of the Campbell-Shiller VAR and a two-variable cointegrated VAR with the yield spread being the cointegrating vector.

[3] See bbalibor™ Explained at bbalibor web page (www.bbalibor.com).

[4] See www.bankofengland.co.uk/statistics/index.htm, time series: IUMVNEA (1M), IUMAMIJ (3M), IUMVSMA (6M), and IUMVYRA (12M), each consisted of 378 observations.

2. REHTS and its testing within a VAR framework

According to the REHTS the expected (continuously compounded) one-period holding period return on a bond that has n periods to maturity equals the return on one-period bond increased by the term premium, i.e. [Tzavalis, Wickens 1998; Cuthbertson, Nitzsche 2003; Blangiewicz, Miłobędzki 2009]

$$E_t h_{t+1}^{(n)} = E_t\left[\ln P_{t+1}^{(n-1)} - \ln P_t^{(n)}\right] = R_t^{(1)} + \theta_t^{(n)}, \tag{1}$$

where $P_t^{(n)}$ is the price at time t of a pure discount bond with face value of £1 and n periods to maturity, $R_t^{(1)}$ is the certain (riskless) one-period interest rate, E_t is the expectations operator conditional on information available to investors at time t, $\theta_t^{(n)}$ is one-period time-varying term premium which compensates for the risk of investing in n-period bond ($n \geq 2$, $t \in R_+$). Eq. (1) reads that the expected excess one-period holding period return, $E_t h_{t+1}^{(n)} - R_t^{(1)}$, reflects changes in the one-period time-varying term premium, $\theta_t^{(n)}$. In case $\theta_t^{(n)} = 0$ or to some other constant the REHTS stands in its pure form (PREHTS). $\theta_t^{(n)} > \theta_t^{(n-1)} > \ldots > \theta_t^{(2)}$ indicates the liquidity preferences form of REHTS to hold (LPREHTS).

The continuous compounding implies that $\ln P_t^{(n)} = -nR_t^{(n)}$, where $R_t^{(n)}$ is the spot yield on long-term bond. Thus

$$h_{t+1}^{(n)} = nR_t^{(n)} - (n-1)R_{t+1}^{(n-1)} = n\left[R_t^{(n)} - \frac{n-1}{n}R_{t+1}^{(n-1)}\right]. \tag{2}$$

Then using Eqs. (1) and (2) yields[5]

$$R_t^{(n)} = \frac{1}{n}\sum_{i=0}^{n-1} E_t R_{t+i}^{(1)} + \Theta_t^{(n)}. \tag{3}$$

Eq. (3) says that the n-period interest rate is the average expected one-period interest rate over n periods increased by the rolling over term premium, $\Theta_t^{(n)} = \frac{1}{n}\sum_{i=0}^{n-1} E_t \theta_{t+i}^{(n-i)}$ [6].

[5] To obtain this result Eq. (2) is substituted into the expected one-period holding period return, $E_t h_{t+1}^{(n)}$, to yield $E_t\left[R_{t+1}^{(n-1)} - R_t^{(n)}\right] = \frac{1}{n-1}\left[R_t^{(n)} - R_t^{(1)}\right] + \left(\frac{1}{n} - 1\right)\theta_t^{(n)}$, which is then iterated forwards and gives Eq. (3).

[6] In other words the return from holding n-period bond from time t to maturity should equal the return from rolling one-period bond over n periods and the rolling over term premium.

From Eqs. (1)-(3) it is deduced that [Tzavalis, Wickens 1998; Cuthbertson, Bredin 2001; Cuthbertson, Nitzsche 2003]

$$eh_{t+1}^{(n)} = h_{t+1}^{(n)} - E_t h_{t+1}^{(n)} = -\left[\left(E_{t+1} - E_t\right) \sum_{i=1}^{n-1} R_{t+i}^{(1)} + \left(E_{t+1} - E_t\right) \sum_{i=1}^{n-1} \theta_{t+i}^{(n-i)} \right]. \tag{4}$$

An unanticipated change in one-period holding period return must be due to either a revision to expectations about future short rates, $eR_{t+1}^{(1)} = \left(E_{t+1} - E_t\right) \sum_{i=1}^{n-1} R_{t+i}^{(1)}$, or to revisions to the future one-period term premia, $e\theta_{t+1}^{(n)} = \left(E_{t+1} - E_t\right) \sum_{i=1}^{n-1} \theta_{t+i}^{(n-i)}$.

Subtracting $R_t^{(1)}$ from both sides of Eq. (3) and rearranging terms gives

$$S_t^{(n,1)} = E_t \sum_{i=1}^{n-1} \left(1 - \frac{i}{n}\right) \Delta R_{t+i}^{(1)} + \Theta_t^{(n)}. \tag{5}$$

Eq. (5) indicates that the observed yield spread, $S_t^{(n,1)}$, should equal the optimal forecast of future changes in the short rates ('perfect foresight spread'), $E_t \sum_{i=1}^{n-1} \left(1 - \frac{i}{n}\right) \Delta R_{t+i}^{(1)}$, and the rolling over term premium. This is to say that at time t only information contained in the yield spread and the rolling over term premium should help predict future changes in the short rates. An implication of the latter is twofold: (i) the yield spread should Granger cause future changes in the short rates, and (ii) in case the term premium is not time-varying the expected excess one-period holding period return is constant and should neither depend upon its past values nor upon past values of the actual spread and changes in the future short rates. All these give rise to a number of tests to be implemented using the Campbell-Shiller VAR methodology.

A three-variable extension of the Campbell-Shiller VAR is built in the lines originated by Tzavalis and Wickens, 1998. Firstly, it is assumed that both the long and the short rate and the one-period holding period return are integrated of order one variables. In case the term premium is stationary albeit time-varying Eqs. (1) and (5) imply the existence of two cointegrating vectors: the yield spread, $S_t^{(n,1)} = R_t^{(n)} - R_t^{(1)}$, and the excess one-period holding period return, $h_t^{(n)} - R_{t-1}^{(1)}$. In such circumstances $\tilde{x}_t = \left[S_t^{(n,1)} \;\; \Delta R_t^{(1)} \;\; h^{(n)} - R_{t-1}^{(1)} \right]'$ is a stationary vector process that can be written as a demeaned VAR of order p, $x_t = \sum_{j=1}^{p} A_j x_{t-j} + \xi_t$, which in companion form is

$$z_t = A z_{t-1} + u_t, \tag{6}$$

where $z_t = \begin{bmatrix} x_t & x_{t-1} & \dots & x_{t-p+1} \end{bmatrix}'$ and $u_t = \begin{bmatrix} \xi_{1,t} & \xi_{2,t} & \xi_{3,t} & 0 & \dots & 0 \end{bmatrix}'$. Vector z_t summarizes the whole history of x_t up to time t so that it is employed as the information set.

Next, using the VAR predictions of the expected excess one-period holding period return, $E_t h_{t+1}^{(n)} - R_t^{(1)} = e3' A z_t$, and the future changes in short-term interest rates, $S_t^{*(n,1)} = E_t \sum_{i=1}^{n-1} \left(1 - \frac{i}{n}\right) \Delta R_{t+i}^{(1)} = e2' A \left[I - \frac{1}{n}\left(I - A^n\right)\left(I - A\right)^{-1} \right] \left(I - A\right)^{-1} z_t$ (theoretical spread), are made in which $e2$ and $e3$ are $(3p \times 1)$ selection vectors with unity in the second and third rows, respectively, and zeros elsewhere, to pick up from the system the change in short rate, $\Delta R_t^{(1)} = e2' z_t$, and the excess one-period holding period return, $h_t^{(n)} - R_{t-1}^{(1)} = e3' z_t$ [Campbell, Shiller 1991; Tzavalis, Wickens 1998; Bataa, Kim, Osborn 2006].

With a time-invariant term premium the first prediction from the VAR should equal some constant and since all variables in the system are expressed in deviations from their means this requires a set of $3p$ linear restrictions be such that

$$e3' A = 0, \tag{7}$$

which can be tested with the use of a Wald test. Under the null the relevant test statistics is distributed as the $\chi^2(3p)$ variable.

In the same circumstances the second prediction from the VAR, the theoretical spread, should equal the actual spread, $S_t^{*(n,1)} = S_t^{(n,1)}$. This implies now that a set of $3p$ nonlinear cross-equation restrictions be such that

$$f(a) = e1' - e2' A \left[I - (1/n)\left(I - A^n\right)\left(I - A\right)^{-1} \right] \left(I - A\right)^{-1} = 0, \tag{8}$$

where $e1$ is a $(3p \times 1)$ selection vector with unity in the first row and zeros elsewhere to pick up from the VAR the actual spread, $S_t^{(n,1)} = e1' z_t$. Its significance is tested with a Wald test[7].

The equality of the actual and the theoretical spread provides two other VAR metrics to be used in testing for the validity of PREHTS: the variance ratio

[7] The relevant test statistics is $W = f(a)' \times \left[\frac{\partial f(a)}{\partial a'} \hat{\Sigma}_{aa} \frac{\partial f(a)}{\partial a} \right]^{-1} \times f(a)$, where $\hat{\Sigma}_{aa}$ is either the standard or the Eicker-White heteroscedasticity consistent variance-covariance matrix of the VAR parameters estimator. Under the null and the standard conditions of the error term u_t it is distributed as the $\chi^2(3p)$ variable.

$$VR = \frac{\sigma^2\left[S_t^{*(n.1)}\right]}{\sigma^2\left[S_t^{(n,1)}\right]} = 1, \tag{9}$$

and the correlation coefficient

$$\rho = corr\left[S_t^{*(n,1)}, S_t^{(n,1)}\right] = 1. \tag{10}$$

Additionally, two series should move close to each other across time.

Now that $\frac{\rho}{\sqrt{VR}}$ is the unbiased OLS estimator of the slope in the regression of actual spread onto theoretical spread, either both the variance ratio and the correlation coefficient estimates should equal unity or the first must be an inverse of the other [Tzavalis, Wickens 1998]. In case the variance ratio estimate is less (greater) than unity and the correlation coefficient estimate is close to unity, the slope is less (greater) than unity and the actual spread is more (less) volatile than the theoretical spread, the optimal predictor of future short rates. On the other hand, if both the variance ratio and the correlation coefficient estimates are far from unity, the actual spread and the theoretical spread move away from each other across time. The overreaction (underreaction) might be due to a time-varying term premium.

A time-variability of the term premium can be inferred from the VAR using the observed excess one-period holding period return from the n-period bond. Since Eqs. (1) and (4) read that

$$h_{t+1}^{(n)} - R_t^{(1)} = \theta_t^{(n)} - \left[eR_{t+1}^{(1)} + e\theta_{t+1}^{(n)}\right], \tag{11}$$

the sources of variability of the latter are threefold: (i) a term premium, $\theta_t^{(n)}$, a revision to expectations about the future short rates, $eR_{t+1}^{(1)}$, and revisions to the future one-period term premia, $e\theta_{t+1}^{(n)}$. Thus it is the error term in the third equation of the VAR, $u_{3,t} = e3'u_t$, that reflects a 'surprise' in the excess one-period holding period return. The estimates of R_3^2 and $(1-R_3^2)$, respectively, indicate a proportion of its variation that is due to variation in the term premium and a joint variation that is due to 'news' about the future short rates and 'news' about the future term premia.

To asses the relative importance of variation in expectations about the future term premia it is to notice that [Cuthbertson, Nitzsche 2003]

$$eR_{t+1}^{(1)} = \left(E_{t+1} - E_t\right)\sum_{i=1}^{n-1} R_{t+1}^{(1)} = \left(E_{t+1} - E_t\right)\left[\left(n-1\right)R_t^{(1)} + \sum_{i=1}^{n-1}\sum_{j=1}^{i}\Delta R_{t+j}^{(1)}\right] =$$

$$= \left(E_{t+1} - E_t\right)\sum_{i=1}^{n-1}\sum_{j=1}^{i}\Delta R_{t+j}^{(1)} . \tag{12}$$

Thus the estimates of $e\theta_{t+1}^{(n)}$ are to be obtained from the VAR residuals:

$$\hat{e}\theta_{t+1}^{(n)} = -\hat{e}R_{t+1}^{(1)} - \hat{e}h_{t+1}^{(n)} =$$

$$= e2'\left[\left(n-1\right)I + \left(n-2\right)A + \left(n-3\right)A^2 + \ldots + \left(n-\left(n-1\right)A^{n-2}\right)\right]\hat{u}_{t+1} - \hat{\xi}_{3,t+1}. \qquad (13)$$

Now, in case revisions to the future term premia are small ($e\theta_{t+1}^{(n)} \approx 0$), the 'surprise' in one-period holding period return wholly reflects 'news' about the future short rates and the following additional metrics apply:

$$\frac{\sigma^2\left[eR_{t+1}^{(n)}\right]}{\sigma^2\left[eh_{t+1}^{(n)}\right]} = 1, \qquad (14)$$

$$\rho\left[eR_{t+1}^{(n)}, eh_{t+1}^{(n)}\right] = -1. \qquad (15)$$

Then it is concluded that the estimate of $\left(1-R_3^2\right)$ indicates a proportion of the excess holding period return that is solely due to variation in 'news' about the future short rates.

3. Empirical results

The LIBOR series of all maturities considered in the paper are the end of month rates. Their performance is depicted in Figure 1. The series rarely pass through their mean levels, which suggests they may not be stationary. Thus the validation of REHTS in the London Interbank Market sets off with the testing for stationarity of LIBORs and variables entering the VAR (actual yield spread, change in the short rate, ex-post excess one-period holding period return). In doing so the KPSS and the Leybourne testing procedures have been employed [Kwiatkowski et al. 1992; Leybourne 1995]. Their results gathered in Table 1 (see Appendix) indicate that LIBOR 1M-12M series are integrated of order one, and $S_t^{(n,1)}$, $\Delta R_t^{(1)}$ and $h_t^{(n)} - R_{t-1}^{(1)}$ series are integrated of order zero.

The results from the VAR are stacked in Table 2 (see Appendix). The lag length p in the VAR for each maturity is chosen according to the Schwartz-Bayesian information criterion but it is occasionally increased to remove autocorrelation in residuals[8]. The first two equations in the system (yield spread, and change in the short rate equation) have a relatively moderate to large predictive power as reflected by the

[8] For the $(n,1) = (6,1)$ pair of maturities it is not possible to remove autocorrelation in residuals in the second equation of the VAR (change in the short rate) without its overparametrizing so that much caution should be retained while using the estimation results in the further analysis.

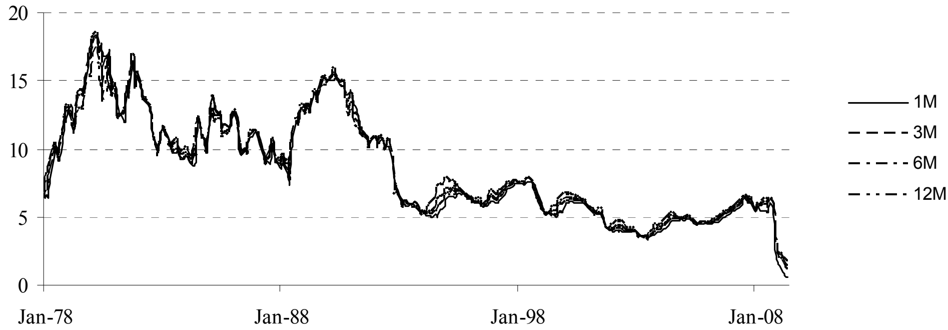

Fig. 1. Monthly sampled LIBORs, January 1978-June 2009

Source: own work.

Table 1. Testing for unit roots and stationarity results

Variable	Test statistics					
	KPSS				Leybourne	
	level	lag	trend	lag	$t_{\_max}$	lag
LIBOR						
1M	**1.765**	16	0.081	16	–0.539 [1]	0
3M	**1.766**	16	0.084	16	–0.549 [1]	0
6M	**1.801**	16	0.088	16	–0.535 [1]	0
12M	**1.845**	16	0.093	16	–0.484 [1]	0
ΔLIBOR						
1M	0.161	16	0.065	16	**–18.109** [1]	0
3M	0.158	16	0.067	16	**–11.472** [1]	1
6M	0.156	16	0.066	16	**–18.437** [1]	0
12M	0.152	16	0.063	16	**–17.787** [1]	0
Yield spred						
3M1M	0.386	16	0.067	16	**–11.187** [3]	0
6M1M	0.422	16	0.031	16	**–7.783** [1]	0
12M1M	**0.507**	16	0.037	16	**–5.606** [1]	0
Ex-post excess one-period holding period return						
3M	0.368	16	0.067	16	**–12.444** [1]	1
6M	0.365	16	0.071	16	**–19.829** [1]	0
12M	0.354	16	0.075	16	**–18.547** [1]	0

Notes to Table 1:

The optimal lag length (third, fifth and seventh column) is set on the ground of either the Schwarz (Leybourne test) or the Newey-West (KPSS test) criterion, see Hobijn *et* al. 1988.

Values of the test statistics causing the rejection of the null at 5 percent significance level [series is I(1) in the Leybourne test; series is stationary around level (trend) in case of the KPSS test] are in bold.

Types of the Leybourne auxiliary regressions: (1) no deterministic components, (2) constant present in the regression, (3) both constant and trend present in the regression.
Source: own computations.

Table 2. Summary statistics for VAR $x_t = [S_t^{(n,1)}\ \Delta R_t^{(1)}\ h_t - R_{t-1}^{(1)}]'$

$(n, 1)$	VAR order p	Autocorrelation[(a)]						R^2			Granger non-causality[(b)]
		LM(12)			LM(6)						
		$S_t^{(n,1)}$	$\Delta R_t^{(1)}$	$h_t^{(n)} - R_{t-1}^{(1)}$	$S_t^{(n,1)}$	$\Delta R_t^{(1)}$	$h_t^{(n)} - R_{t-1}^{(1)}$	$S_t^{(n,1)}$	$\Delta R_t^{(1)}$	$h_t^{(n)} - R_{t-1}^{(1)}$	
(3, 1)	5	15.823 (0.199)	20.377 (0.060)	16.677 (0.162)	8.308 (0.216)	8.936 (0.177)	7.937 (0.243)	0.337	0.193	0.057	28.602 (0.000)
(6, 1)	5	11.828 (0.460)	22.231 (0.035)	18.513 (0.101)	7.823 (0.251)	2.423 (0.877)	6.017 (0.421)	0.556	0.196	0.032	21.598 (0.001)
(12, 1)	7	16.267 (0.179)	14.776 (0.2540)	20.287 (0.062)	6.845 (0.335)	6.365 (0.383)	12.264 (0.056)	0.752	0.216	0.060	22.028 (0.002)

Notes to Table 2:

[(a)] Estimates of the LM test statistics for autocorrelation of order $s = 12$ [6] under the null of no autocorrelation distributed as $\chi^2(12)$ [$\chi^2(6)$]; the relevant p-values in brackets under the estimates; [(b)] Estimates of the test statistics for Granger non-causality from $S_t^{(n,1)}$ to $\Delta R_t^{(1)}$ under the null $[a_{21}^{(1)} = a_{21}^{(2)} = \ldots = a_{21}^{(p)} = 0]$ distributed as $\chi^2(p)$ variable; the relevant p-values in brackets under the estimates.

Source: own computations.

Table 3. VAR restrictions and other metrics

$(n,1)$	Excess one-period holding period return is not time-varying	Actual spread $S_t^{(n,1)}$ and theoretical spread $S_t^{*(n,1)}$			
	$e3'A = 0$ [(a)]	$S_t^{*(n,1)} = S_t^{(n,1)}$ [(a)]	$\sigma^2\left[S_t^{*(n,1)}\right] / \sigma^2\left[S_t^{(n,1)}\right]$ variance ratio [(b)]	$\sigma^2\left[S_t^{*(n,1)}\right] / \sigma^2\left[S_t^{(n,1)}\right]$ confidence interval	$\rho\left[S_t^{*(n,1)}, S_t^{(n,1)}\right]$ [(b)]
$(3,1)$	W(15) = 22.040 (0.107)	W(15) = 44.025 (0.000)	0.641 (0.170)	0.436 1.102	0.851 (0.077)
$(6,1)$	W(15) = 8.566 (0.899)	W(15) = 13.557 (0.559)	0.491 (0.186)	0.286 1.011	0.884 (0.099)
$(12,1)$	W(21) = 23.491 (0.318)	W(21) = 21.749 (0.414)	0.552 (0.294)	0.257 1.384	0.858 (0.125)

Notes to Table 3:

[(a)]The relevant p-values in brackets under the Wald test statistics estimates; [(b)]The relevant standard errors from the bootstrap under the variance ratio and the correlation estimates. The recursive bootstrap has been applied with 50000 replications. The bootstrap series have been used to estimate the VAR, and then to compute artificial 'actual' and 'theoretical' spreads, their correlation coefficients, variance ratios and confidence intervals.

Source: own computations.

estimates of their coefficients of determination, nevertheless a huge lot of unexplained variation in the ex-post excess one-period holding period return equation is left to be attributed to revisions to the expectations about future short rate and future term premia. The yield spread $S_t^{(n,1)}$ turns out to Granger cause the future changes in short rates for all maturities.

Table 3 (see Appendix) reports the results of testing for the validity of REHTS with a time-varying term premium using restrictions set on the VAR parameters and the other VAR metrics. In all cases the restriction that the excess one-period holding period return is not time-varying ($e3'A = 0$) is not rejected. The same conclusion is reached on the ground of the Wald test statistics for $H_0 : S_t^{*(n,1)} = S_t^{(n,1)}$ for all maturities but the three-month LIBOR.

Inspection of Figure 2a-2c and 3a-3c on which scatter plots of the theoretical spread versus the actual spread and their co-movement across time are displayed, respectively, gives strong evidence that the term premium is not time-varying, also for the three-month LIBOR. The empirical points on all scatter plots are highly concentrated around the approximate 45-degree straight line indicating that for all n

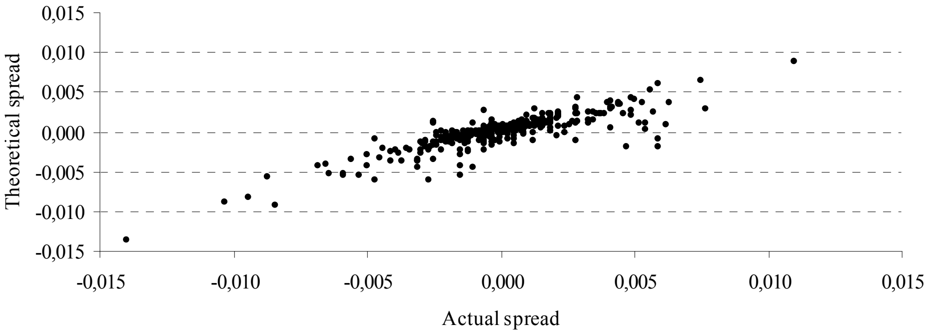

Fig. 2a. Theoretical versus empirical spread, 3M-1M

Source: own work.

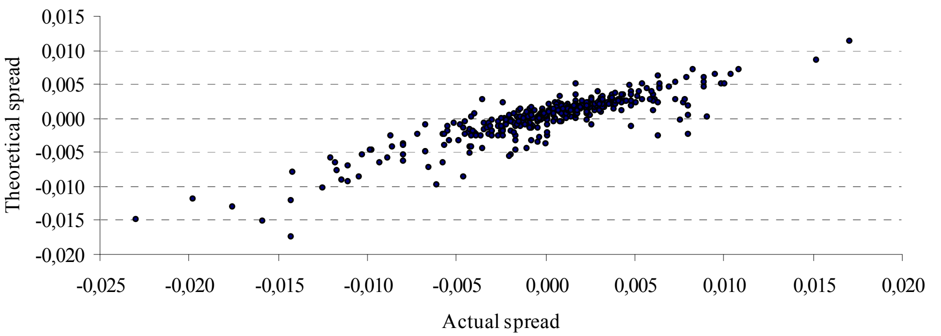

Fig. 2b. Theoretical versus empirical spread, 6M-1M

Source: own work.

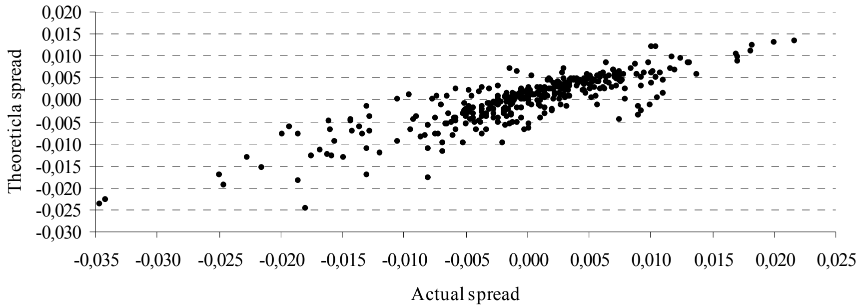

Fig. 2c. Theoretical versus empirical spread, 12M-1M

Source: own work.

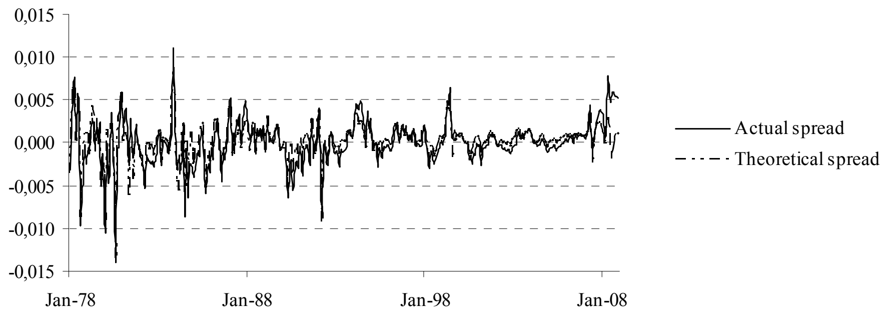

Fig. 3a. Theoretical and actual spread, 3M-1M

Source: own work.

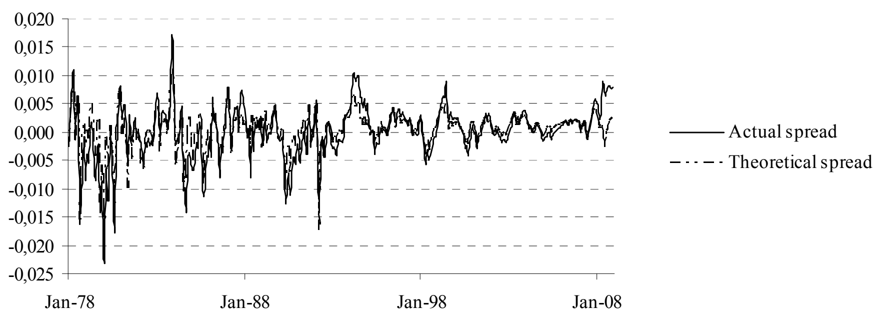

Fig. 3b. Theoretical and actual spread, 6M-1M

Source: own work.

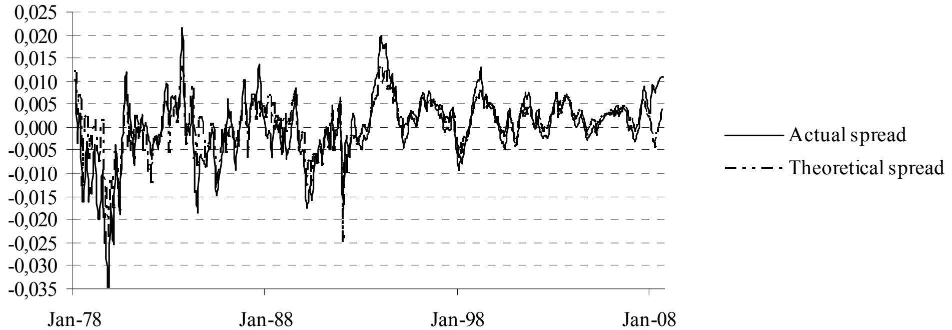

Fig. 3c. Theoretical and actual spread, 12M-1M

Source: own work.

correlation between $S_t^{*(n,1)}$ and $S_t^{(n,1)}$ is rather close to unity. The estimates of $corr\left[S_t^{*(n,1)}, S_t^{(n,1)}\right]$ differing from unity by less than their two standard deviations support this preposition. The theoretical spread and the actual spread series show very close correspondence which stands against the overreaction (underreaction) hypothesis. The LIBORs 1M-12M display almost the same volatility. Although the variance ratio (VR) estimate differs from unity by more than its two standard deviations for three and six-month maturities, the estimated 95 per cent confidence interval for the variance ratio covers unity in all cases.

Table 4. Variance decomposition: news abort short rates and one period return

$(n,1)$	$\sigma^2\left[eR_{t+1}^{(1)}\right]/\sigma^2\left[eh_{t+1}^{(n)}\right]$		$\rho\left[eR_{t+1}^{(1)}, eh_{t+1}^{(n)}\right]$ [(a)]
	variance ratio [(a)]	confidence interval	
$(3,1)$	0.917 (0.066)	0.790 1.048	–0.976 (0.007)
$(6,1)$	1.050 (0.125)	0.809 1.299	–0.981 (0.011)
$(12,1)$	1.306 (0.247)	0.832 1.794	–0.961 (0.027)

Notes to Table 4:

[(a)] The relevant standard errors from the bootstrap under the variance ratio and the correlation estimates. The recursive bootstrap has been applied with 50000 replications. The bootstrap series have been used to estimate the VAR, and then to compute artificial ‘actual’ and ‘theoretical’ spreads, their correlation coefficients, variance ratios and confidence intervals.

Source: own computations.

From Table 4 (see Appendix) it is deduced for all maturities that almost the whole variation in the excess one-period holding period return is due to variation in 'news' about future changes in the short rate, and is not due to variation in 'news' about future term premia. This is why both the estimate of variance ratio $\frac{\sigma^2\left[eR_{t+1}^{(1)}\right]}{\sigma^2\left[eh_{t+1}^{(n)}\right]}$ differs from unity by less than its two standard deviations, as well as the estimated 95 per cent confidence interval for variance ratio covers unity for all maturities. The estimates of correlation coefficient $corr\left[eR_{t+1}^{(1)}, eh_{t+1}^{(n)}\right]$ are close to minus unity for all n but $n = 3$. Since the coefficient of determination estimates in the excess one-period holding period return equations ranges from 0.032 to 0.06, the proportion of the excess holding period return that is due to variation in 'news' about future short-term interest rates is as high as 96.8 per cent.

4. Conclusion

Testing for validity of REHTS with a time-varying term premium requires an extension of the two-variable VAR of Campbell and Shiller including the actual spread and the change in short rate by adding a third variable, the excess one period holding period return, which may capture movements in (stationary) term premium.

For all maturities in sterling considered in the paper (ranging from one to twelve months) the PREHTS with a constant term premium is supported by the London Interbank Market data. Unexpected changes in the excess one-period holding period returns are solely due to revisions to forecasts about future short rates.

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STRUKTURA TERMINOWA STÓP PROCENTOWYCH LIBOR DLA FUNTA BRYTYJSKIEGO

Streszczenie: W artykule przedstawione są wyniki badania poświęconego strukturze terminowej stóp LIBOR (*London Interbank Offered Rates*) dla depozytów w funcie szterlingu. Badanie oparte jest o trójwymiarowy model VAR, którego poszczególne równania odzwierciedlają spred stóp procentowych (*yield spraed*), zmianę stopy zwrotu dla depozytu o krótszej zapadalności (*change in the short rate*) oraz nadwyżkową, okresową stopę zwrotu (*excess holding period yield*). W estymacji i weryfikacji modelu wykorzystano miesięczne szeregi czasowe stóp procentowych dla depozytów o zapadalnościach jednego, trzech, sześciu oraz dwunastu miesięcy z okresu od stycznia 1978 do czerwca 2009 roku, udostępnione przez Bank Anglii. Wyniki empiryczne dla rozważanych zapadalności wskazują na to, że spred stóp procentowych ma duże zdolności predykcyjne w odniesieniu do zmiany stopy zwrotu z depozytów jednomiesięcznych. Nie dają też podstaw do odrzucenia hipotezy głoszące stałość w czasie premii płynności. Pozwalają one także twierdzić, że niespodziewane zmiany bieżących, jednomiesięcznych zwrotów z depozytów dla wszystkich zapadalności są w całości spowodowane zmianą oczekiwań uczestników rynku w stosunku do przyszłych stóp jednomiesięcznych, nie są natomiast spowodowane zmianą ich oczekiwań odnoszących się do przyszłych premii płynności.